

Historic, Archive Document

Do not assume content reflects current scientific knowledge, policies, or practices.

1969

ROOT COMPETITION

BETWEEN
PONDEROSA PINE SEEDLINGS
AND GRASS

M.M. LARSON
GILBERT H. SCHUBERT

USDA FOREST SERVICE

Research Paper RM - 54

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

USDA Forest Service
Research Paper RM-54

1969

Root Competition Between Ponderosa Pine Seedlings and Grass

by

M. M. Larson, Forest Physiologist

and

Gilbert H. Schubert, Principal Silviculturist

Rocky Mountain Forest and Range Experiment Station¹

¹Central headquarters maintained at Fort Collins, in cooperation with Colorado State University; authors are located at Flagstaff, in cooperation with Northern Arizona University. Larson is now with the Forestry Department, Ohio Agricultural Research and Development Center, Wooster, Ohio.

CONTENTS

	<u>Page</u>
Introduction	1
Materials and methods	1
Glass-faced planter boxes	1
Field plots	1
Results with glass-faced planter boxes	2
First growing season	2
Second growing season	3
Results of field tests	5
Discussion and conclusions	9
Recommendations	11
Literature cited	11

ROOT COMPETITION BETWEEN PONDEROSA PINE SEEDLINGS AND GRASS

M. M. Larson and Gilbert H. Schubert

Introduction

Grass is a common ground cover throughout the ponderosa pine (*Pinus ponderosa* Laws.) forests of the Southwest. Although a valuable forage resource, its presence is definitely detrimental to initial establishment of coniferous reproduction. Certain grasses, however, seem to compete less intensely than others with pine seedlings. This difference in competitiveness is exemplified by two native bunchgrasses: Arizona fescue (*Festuca arizonica* Vasey), a strong competitor, and mountain muhly (*Muhlenbergia montana* (Nutt.) Hitchc.), a mild competitor (Pearson 1942). This Paper reports on investigations of the tree-grass relationship on the Fort Valley Experimental Forest near Flagstaff, Arizona.

Materials and Methods

The study was conducted in two environments: glass-faced planter boxes set in the ground at the Fort Valley nursery, and field plots in a nearby old clearcut opening in a ponderosa pine stand. Both locations were at an elevation of about 7,400 feet.

Glass-Faced Planter Boxes

Dormant ponderosa pine, Arizona fescue, and mountain muhly seedlings were planted on April 12, 1963, in nine glass-faced boxes previously described by Larson (1962) and Lavin (1961) to study root development. These boxes, 2 feet by 3 inches at the top and 2 feet deep, were slid into wooden frames that had been buried in the ground at a 30° angle from vertical. The side of the box with the removable glass face was placed downward and the top level with the soil surface.

Moist, gravelly, clay loam soil, derived from basalt, was dug from a nearby pit and transferred to the boxes at approximately the same original horizons. Adequate drainage was provided through a layer of coarse volcanic cinders and holes drilled in the bottom of the boxes. After each box was filled with soil it was lifted from the wooden frame, placed flat on the ground, and the glass plate removed.

Seedlings were then placed on the exposed soil at regular planting depth with roots extended. Two 2-0 ponderosa pines from the adjacent nursery beds were planted 1 foot apart in each of the nine boxes. Arizona fescue and mountain muhly plants from a nearby natural grass stand were separated into very small individual entities, root pruned to 4 inches, and then planted in six of the boxes, three for each of the two grass species. Three grass transplants were planted on each side of

the pine. The glass was then replaced carefully to avoid disturbing the roots and the box inserted into the frame.

The plants were watered immediately after planting and at weekly intervals during the spring and fall drought periods. Each watering was equivalent to 0.5 inch of rain.

Roots were measured twice weekly during the spring of the first growing season. The interval between subsequent measurements was adjusted according to the amount of new root growth. Heights were measured several times during the growing season.

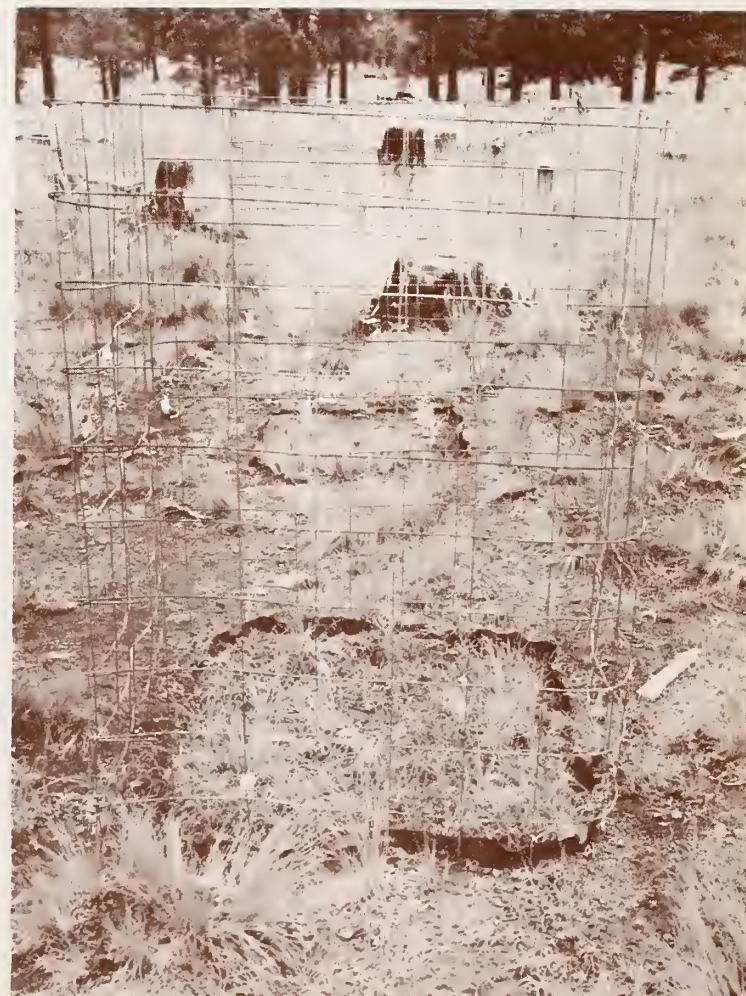
Final measurements were made at the end of two full growing seasons. After the depth of the pine root system was measured, the pine and grass seedlings were carefully washed from the soil. New root tips on the pines were counted, then all plants were photographed, dried, and weighed.

Field Plots

Two-year-old ponderosa pine seedlings were planted April 25-28, 1964, in six replications each containing six plots — two each of Arizona fescue, mountain muhly, and denuded cover types. Nine pine seedlings, of Arizona seed origin grown at the Bend Nursery in Oregon, were planted at a 1-foot spacing in each of the 3-foot-square plots.

The natural grass stand in the study area consisted almost entirely of the two bunchgrass species arranged as a mosaic of single species clumps up to 6 feet in diameter. Plots were located in the centers of the grass clumps and denuded spots. All six plots of each replication were within a 25-foot-square area.

Figure 1.--Mountain muhly cover type plot planted with nine 2-0 ponderosa pine seedlings, one to each square foot. The black border is the upper edge of the plastic root barrier. White tags indicate the location of some pine seedlings.



Each 3-foot-square plot was surrounded by a root-moisture barrier of 6-mil black plastic film to a depth of 20 inches and a 5-foot woven wire fence to exclude browsing animals (fig. 1). Grass immediately adjacent to the planted pines was repeatedly clipped to 2 inches so that all trees could receive direct sunlight during the noon hours. One randomly selected plot of each cover type in each replication was watered during the drought periods to reduce competition between plants for moisture.

Soil moisture and temperature in the plots were measured with electrical resistance blocks and thermistors, respectively. All moisture and temperature units were calibrated in the laboratory with soil from several depths within the study area. Thermistors were installed in half the plots to measure soil temperature. Two soil moisture units were placed at the 4-inch depth in all unwatered plots and in watered plots of replications 2 and 6. These units were spaced 1 foot apart and 1 foot from the moisture barrier. In addition, two soil moisture units were placed at 8-, 16-, and 24-inch depths in the unwatered plots of replications 1 and 5. The moisture units and thermistors were read at about midday.

Air temperature, relative humidity, and precipitation were measured at the center of the study area. The recording hygrothermograph, set in a wooden shelter open on two sides, measured air temperature and relative humidity at 3 inches above the ground surface.

Water balance of pine seedlings was determined four times during the first growing season. One needle fascicle was detached from each seedling about 10 hours after sunrise, enclosed in clear plastic wrap, and taken to the laboratory. It was found that needles so treated could be stored at room temperatures for up to 18 hours without significant loss of green weight or capacity to resaturate. Needle moisture content (NMC) and water saturation deficit (WSD) were determined by the method described by Harms and McGregor (1962).

The center pine seedling in each plot was excavated on July 14 of the first growing season to determine new root growth. The remaining seedlings were excavated in October 1965 — two full growing seasons after planting. Data recorded for each seedling were (1) total root depth, (2) length of lateral roots, (3)

number of new root tips, (4) total height, and (5) dry weight of tops and roots.

Results with Glass-Faced Planter Boxes

First Growing Season

Fescue roots started growth about 2 weeks earlier than muhly or pine roots. The first new fescue roots appeared on April 26, about 2 weeks after planting. Muhly and pine developed new root tips on May 12. By the end of May all grass plants and 72 percent of the pines had new root growth. The remaining pines started their root growth in June, about 2 months after planting.

The origin of new root growth differed between the pines and grasses. The pines, planted to an average depth of 10 inches, had new roots develop about 2 inches from the ends. The grasses, planted to an average depth of 4 inches, had new roots develop at the ends of the pruned tips.

Grass roots reached the bottom of the 2-foot-deep boxes before the pines. By June 28, 52 fescue and 13 muhly roots penetrated to the bottom of the six boxes containing grass. Roots of 11 pines grew to the bottom of the boxes in July, two more in August, and one in September. Roots of the remaining four pines did not grow to the 2-foot depth the first year.

Growth rates for both pine and grass roots were highest in late May and early June (figs. 2, 3). During this period, growth rates of the five fastest growing roots of each species averaged 2.5 inches per week for pine, 3.7 inches for fescue, and 3.8 inches for muhly. Growth rates of pine roots were similar for the three cover types.

The root growth pattern of the pines differed from that of the grasses. Pine roots generally grew downward at oblique angles or horizontally a few inches and then downward. All grass roots grew nearly straight down. Since total new root growth was measured, the growth measurements for pines do not indicate root depth with respect to ground surface (fig. 2), whereas growth for the grass roots does reflect root depth (fig. 3).

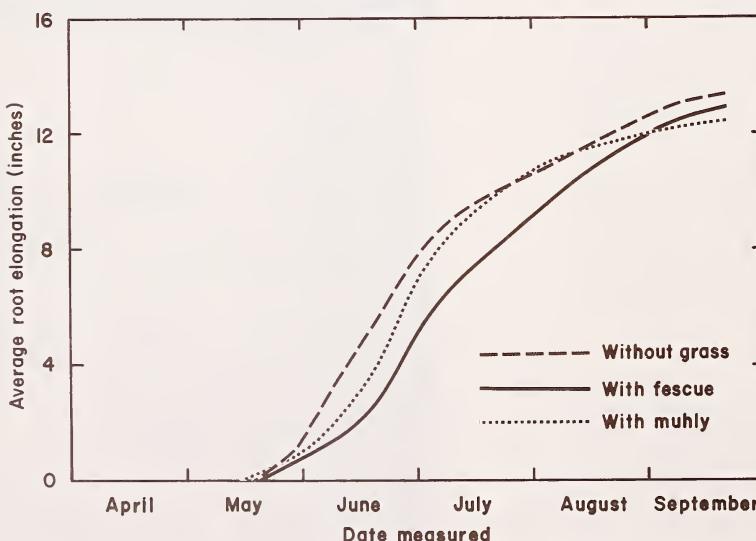
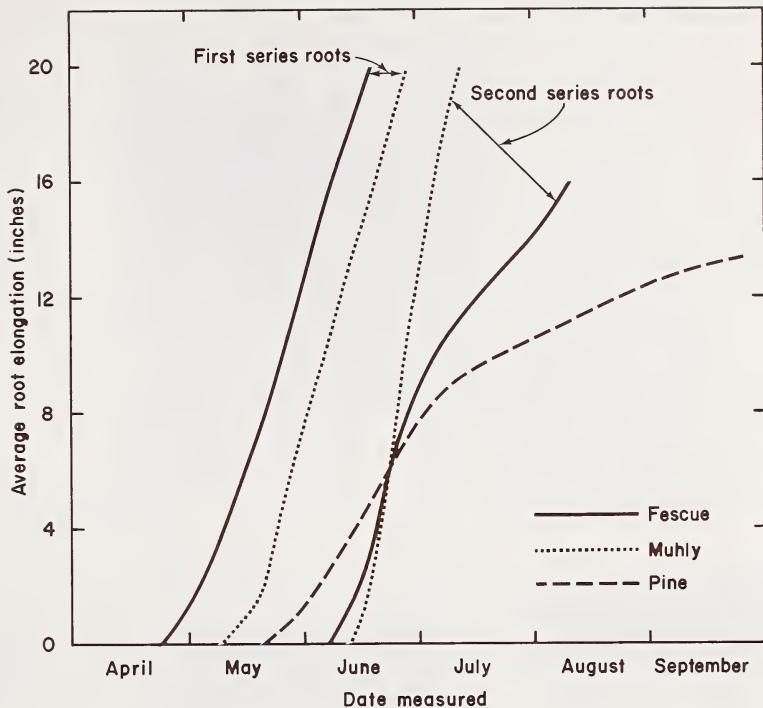


Figure 2.—
Average *ponderosa*
pine root elongation
in glass-faced
planter boxes with
Arizona fescue,
mountain muhly,
and without grass.

Figure 3.--
Comparison of
root elongation
of Arizona fescue,
mountain muhly,
and ponderosa pine
in glass-faced
planter boxes.



Some gross roots grew in direct contact with older pine roots. Growth rates did not change before or after contact with the pine root.

Both gross species produced several series or "flushes" of new main roots. All new sets of "sinker" roots originated near the same point as the first series. The second series of roots was initiated in mid-June. The third series started in late July and early August. Fescue plants produced a fourth series in September.

Second series roots grew at about the same rate as first series (fig. 3). These roots averaged about 3.5 inches per week except for two second series muhly roots, which grew 5 inches per week. Third and fourth series roots grew very slowly.

All second and higher series gross roots were characteristically "woolly" due to their white color and abundance of root hairs. These roots also were larger in diameter than first-order roots. By mid-July the glass-faced surface was covered with gross roots, which obscured the growth of older roots. This dense mat of gross roots rapidly dried out the soil adjacent to the glass during drought periods, even though the plants were watered weekly.

None of the pine terminal buds elongated after planting. However, new buds formed within needle fascicles during midsummer. These new buds grew less than 1 inch during the remainder of the growing season.

Second Growing Season

Pine root growth differed from that of gross roots during the second season also. Roots of pine seedlings planted with gross grew very little the second year. None had new white tips near the bottom of the boxes. In contrast, pines in boxes without

gross developed two to eight thick, white-tipped roots near the bottom by mid-May, and several new, smaller laterals at the 14- to 18-inch depth by late May. All roots ceased growth during the June drought.

Fescue roots were again the first to begin growth the second year. New main roots were evident by mid-April. A slow-growing second series started in late May, followed by a fast-growing third series in late July after the summer rains started.

First new muhly roots appeared in mid-May, about a month later than the fescue and about the same time as the pines in gross-free boxes. Muhly produced a second series root system in late June, but no third series the second year.

Along with the new main root system, both grosses had many small high-order laterals develop on the previous year's main root system. Thirty such small roots were counted on fescue plants in one of the boxes in late April.

Roots of the three species were easily identified. Pine roots were largest in diameter and turned dark brown. Fescue roots changed to dark gray-brown with age, while muhly roots retained their light tan color throughout the 2-year study.

Top growth also differed for the two grosses. Fescue completed its top growth by June 19, when muhly had completed only 63 percent of its growth. By early July, muhly plants had surpassed fescue and averaged 4 inches taller in October (table 1).

When excavated in October, muhly roots appeared to be dormant, whereas many fescue roots still had new white tips. Although total dry weights of the two grosses were similar, the root/shoot ratio of fescue was double that of muhly (table 1).

Pine seedling growth was related to cover treatment. Pine seedlings grew best in boxes without gross (table 2, figs. 4, 5, 6). Both roots and tops were all significantly greater for pines grown without gross than with gross. Pine growth was slightly better in boxes containing muhly than those with fescue.

Table 1.--Average growth per planter box of fescue and muhly grasses after two growing seasons

Grass species	Dry weight			Root/shoot ratio	Leaf height
	Roots ¹	Tops	Total		
- - - <u>Grams</u> - - -					
Fescue	106.0	249.3a	148.7c	2.15d	10.3f
Muhly	76.0	73.2b	149.2c	1.04e	14.3g

¹Root dry weight of the two grasses significantly different at the 10 percent level.

²Any two means in each column not followed by a similar letter are significantly different at the 5 percent level.

Table 2.--Average growth per plant of ponderosa pine seedlings grown in three cover types in planter boxes

Cover type	Dry weight			Root growth	
	Roots	Tops	Net gain ¹	Active laterals ²	Longest root ³
- - - <u>Grams</u> - - -					
Fescue	⁴ 0.57a	0.90c	0.24e	1.2g	20.8i
Muhly	.96a	1.22c	.80e	3.2g	22.8ij
Grass-free	3.37b	4.75d	6.76f	13.2h	27.5j

¹Net gain = dry weight (roots + tops) when harvested minus dry weight (estimated from green weight) when planted.

²First- and second-order lateral roots with white tips were considered "active."

³Measured from root crown to tip of longest lateral root.

⁴Any two means in each vertical column not followed by a similar letter are significantly different at the 5 percent level.

Results of Field Tests

Watered pine seedlings survived better than unwatered seedlings the first growing season. Mortality of watered pines averaged 32 percent, with no significant differences among the three cover types (fig. 7). Mortality of unwatered pines averaged about 72 percent, with significant differences among cover types.

Mortality of watered seedlings was highest during the first winter after planting, whereas mortality of unwatered seedlings was highest during the spring drought soon after planting.

Poor vigor of the pine seedlings was evident during the first

growing season. By July 14, only 6 of the 36 excavated seedlings had new root growth. Furthermore, many of the pines had western gall rust.

Only 57 pines survived the two growing seasons. In general, unwatered pines in the denuded plots grew better than those in a grass cover (table 3). However, unwatered pines in muhly tended to grow better than those in fescue. Watered pines grew equally well in all cover types, but significantly less than those in unwatered bare plots.

Pine seedlings grew less than 2 inches in height during the two growing seasons. Watered fescue and muhly plants averaged 18 inches in height compared to 15 inches for unwatered.

Roots, at end of
second growing
season, washed
from a glass-faced
planter box:

Figure 4.--
Left, ponderosa pine
and Arizona fescue;
Right, pine removed
from fescue.



Figure 5.--
Left, ponderosa pine
and mountain muhly;
Right, pine removed
from muhly.

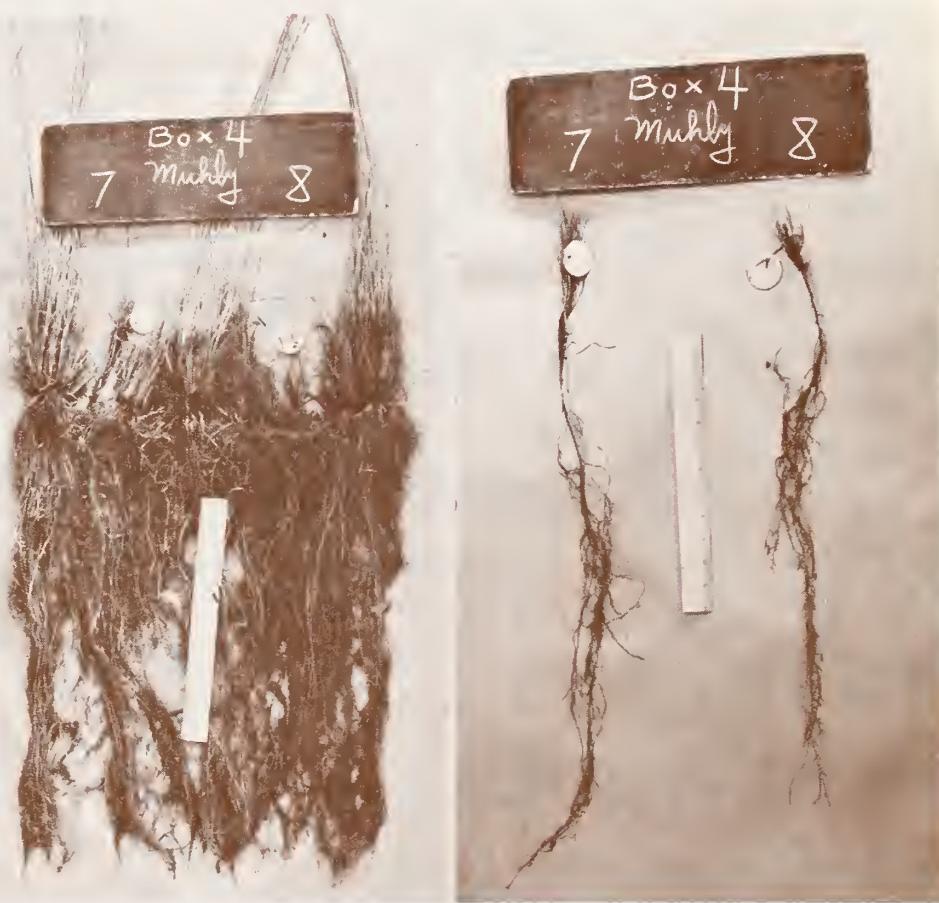


Figure 6.--Ponderosa pine,
grown without competing
grass.

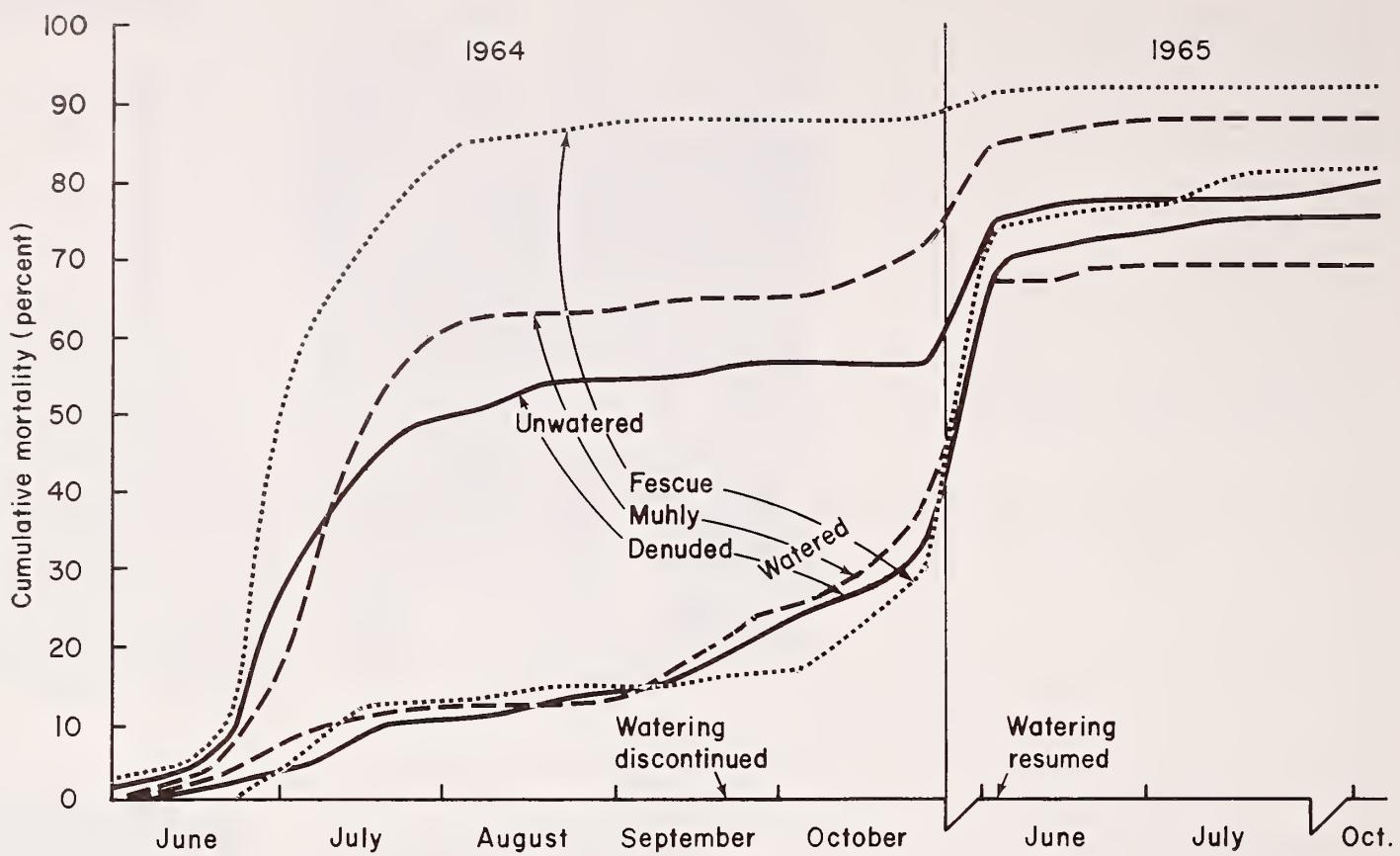


Figure 7.--Cumulative mortality of ponderosa pine seedlings planted in field plots containing Arizona fescue and mountain muhly, 1964 (last count on October 27) and 1965 (last count on October 4).

Table 3.--Average growth of unwatered ponderosa pine seedlings after two growing seasons, by cover type

Cover type	Dry weight		Root growth		
	Roots	Tops	Lateral root length ¹	Deepest root	Active root tips ²
	- - <u>Grams</u> - -		- - <u>Inches</u> - -		
Fescue	30.95a	1.10a	8.90a	18.45a	0.69a
Muhly	1.79b	2.76ab	10.70a	20.81a	2.19a
Denuded	3.73c	6.98b	21.40b	29.09b	6.92b

¹Determined by averaging the four longest lateral roots of each seedling.

²All roots that had light-colored root tips were counted as "active."

³Any two means in each vertical column not followed by a similar letter are significantly different at the 5 percent level.

Soil moisture depletion was least on the denuded and greatest on the fescue plots (figs. 8, 9). Soil moistures were significantly different in early July and October in 1964 and in July and September in 1965. Fescue reduced the moisture potential of soil at the 4-inch depth to or below -15 bars twice during both years, whereas muhly reduced the moisture to this extent only once each year. Soil moisture below 16 inches was continuously adequate for plant growth both years. Soil moisture at the 4-inch depth in watered plots was maintained between 20 to 27 percent.

Thermistors installed in the moisture blocks performed too poorly to warrant a detailed presentation of the results. However, a few did provide consistent readings that indicated

temperature trends. Soil temperatures at the 16- and 24-inch depths increased from the low 40° F. in early May to about 70° F. in mid-August. Noon soil temperatures at 4-inch depths exceeded 75° F. only in the denuded unwatered plots. These temperatures averaged about 2° to 4° F. higher than those at the same depth in unwatered grass-covered plots and up to 16° F. higher than those in watered denuded plots during the warm, dry periods. Soil temperatures in the watered grass plots averaged 3° to 5° F. cooler than those for unwatered plots. During the rainy season, soil temperatures at the 4-inch depth were similar for all plots.

Average weekly air temperatures at 3 inches above the ground did not exceed 68° F. during the two growing seasons

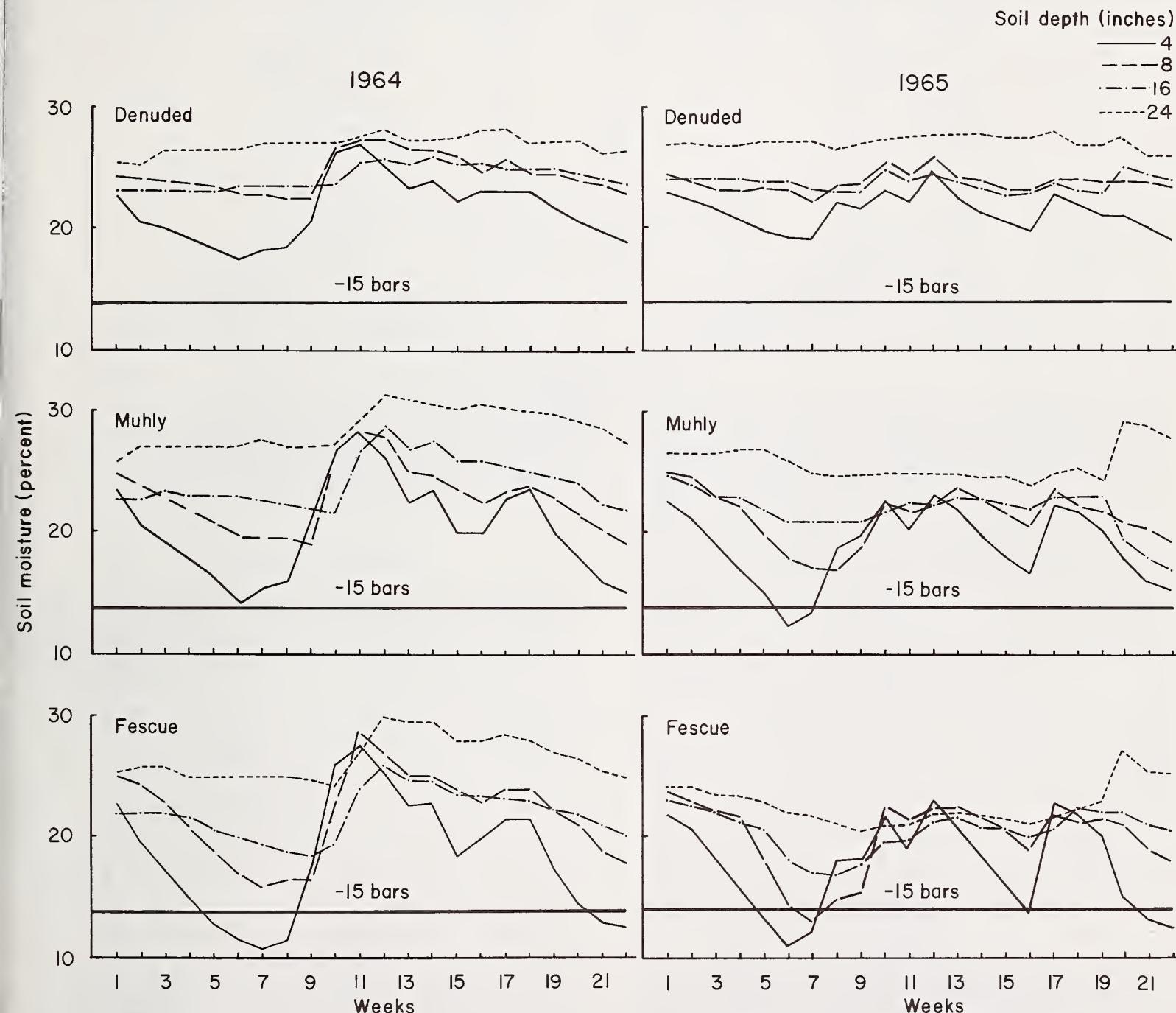


Figure 8.--1964.

Figure 9.--1965.

Soil moisture (weight of water/weight of dry soil in percent) at indicated depths for each unwatered cover type June-October. Moisture content of surface soil at a matric potential of -15 bars is shown.

(fig. 10). Average weekly minimum temperatures were usually under 50° F. with temperatures dropping to or below 32° F. every month. Maximum air temperatures never exceeded 100° F.

About 11 inches of rain fell on the study area each year during the period June 1 to September 30. Relative humidities ranged from 15 to 30 percent at noon during the drought periods, and 40 to 50 percent during the late July-August wet periods.

Needle moisture content (NMC) of the pines averaged 165 percent at time of planting. On June 3, the average NMC of the needles dropped to 140 percent, with no significant treatment differences (table 4). By July 11, near the end of the spring drought, the NMC of live seedlings averaged only 108 percent. At this time the average NMC of watered seedlings was significantly higher than that of unwatered seedlings in each

cover type. Furthermore, the NMC of unwatered seedlings was significantly higher for pines in the denuded plots than in the two grass-covered plots. By August 31 (after several rains) the average NMC of live seedlings was up to 128 percent.

Trends in water saturation deficits (WSD) of seedlings were similar to those of NMC (table 4). Values for WSD and NMC are inversely related to each other. The WSD was 8 percent (near full saturation) at time of planting, 35 percent on July 11 (symptoms of wilting observed) and 28 percent on August 31. Both WSD and NMC were more favorable for survival of unwatered pines than of watered pines on August 31. The water balance of needles (WSD and NMC) was similar for the two collection times — just before sunrise and 10 hours after sunrise.

The NMC and WSD measurements on June 3 were related to the seedlings' ability to survive the ensuing drought period

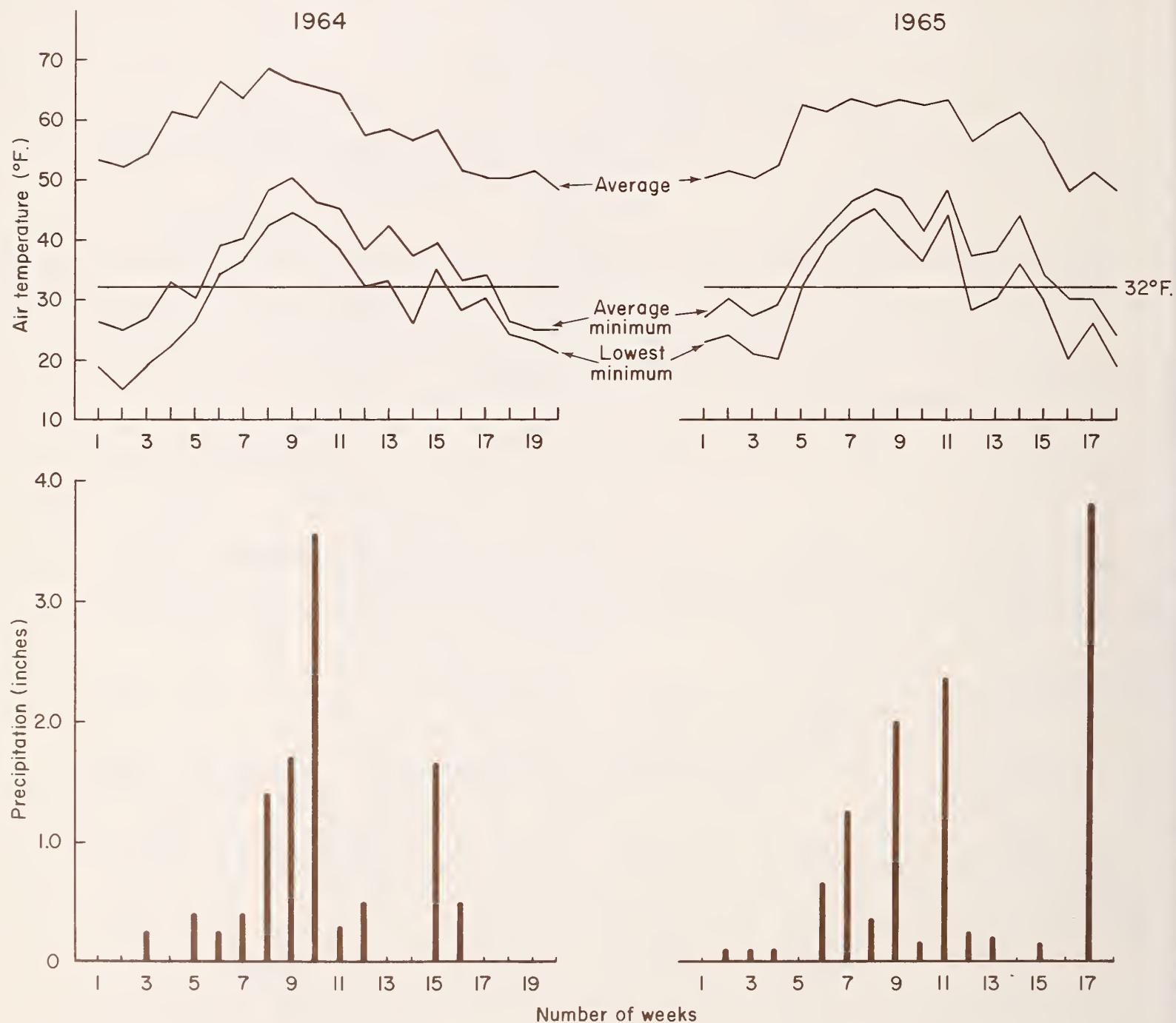


Figure 10.--Air temperatures at 3 inches above ground level (weekly average, weekly average minimum, and lowest minimum recorded each week) and total weekly precipitation during two growing seasons 1964 (June-October) and 1965 (June-September).

Table 4.--Averages of needle moisture content (NMC) and water saturation deficit (WSD) of ponderosa pine seedlings at three dates during the first growing season after planting. (Needles collected 10 hours after sunrise on clear days)

Cover type	Moisture treatment	June 3		July 11		August 31	
		NMC	WSD	NMC	WSD	NMC	WSD
- - - - - - - - <u>Percent</u> - - - - - - -							
Fescue	Watered	143	27	114	37	129	27
	Unwatered	138	30	85	46	142	22
Muhly	Watered	141	27	132	27	126	28
	Unwatered	140	28	84	44	135	21
Denuded	Watered	140	28	128	28	124	25
	Unwatered	137	28	106	29	130	19
Average		140	28	108	35	128	25

(figs. 11, 12). The probability of survival of watered seedlings remained favorable (0.70) even when the June 3 NMC was low (110 percent) or the WSD was high (50 percent). In contrast, the probability of survival of unwatered pine seedlings was less than 50 percent when the NMC was below 146 percent or the WSD was above 25 percent.

Discussion and Conclusions

The investigation of the nature and effect of competition between ponderosa pine seedlings and grasses provided data on growth comparisons and reasons why pines survive and grow better in grass-free environments.

Ponderosa pine seedlings grew best on well-prepared plots. Root and top growth were both significantly greater when pines were grown without competition from grass. The pine seedlings on denuded plots showed an elevenfold greater net gain in dry weight than those grown in competition with grass. Dry weights of roots and tops of pines grown on bare soil were over four times more than for pines grown in grass.

Mountain muhly, a warm-season grower, retarded growth of ponderosa pine seedlings less than did Arizona fescue, a cool-season grower. Net gain in dry weight of pines growing with muhly was nearly four times that of pines growing with fescue.

Grass roots grew faster than pine roots. Main roots of muhly and fescue elongated at a rate 50 percent greater and thereby occupied a given volume of soil sooner than pine roots. At the end of 2 years, dry weight of grass roots was 11 to 16 times greater than the weight of the tree roots for seedlings grown in planter boxes. However, the root weight of the grasses in the boxes was three to four times greater than the root weights reported for a similar volume of soil in an ungrazed mountain muhly pasture in Colorado (Schuster 1964).

Arizona fescue and mountain muhly were more drought tolerant than ponderosa pine seedlings. Grass, in the field plots, recovered original greenness and grew vigorously following the late spring-early summer drought when the soil moisture was

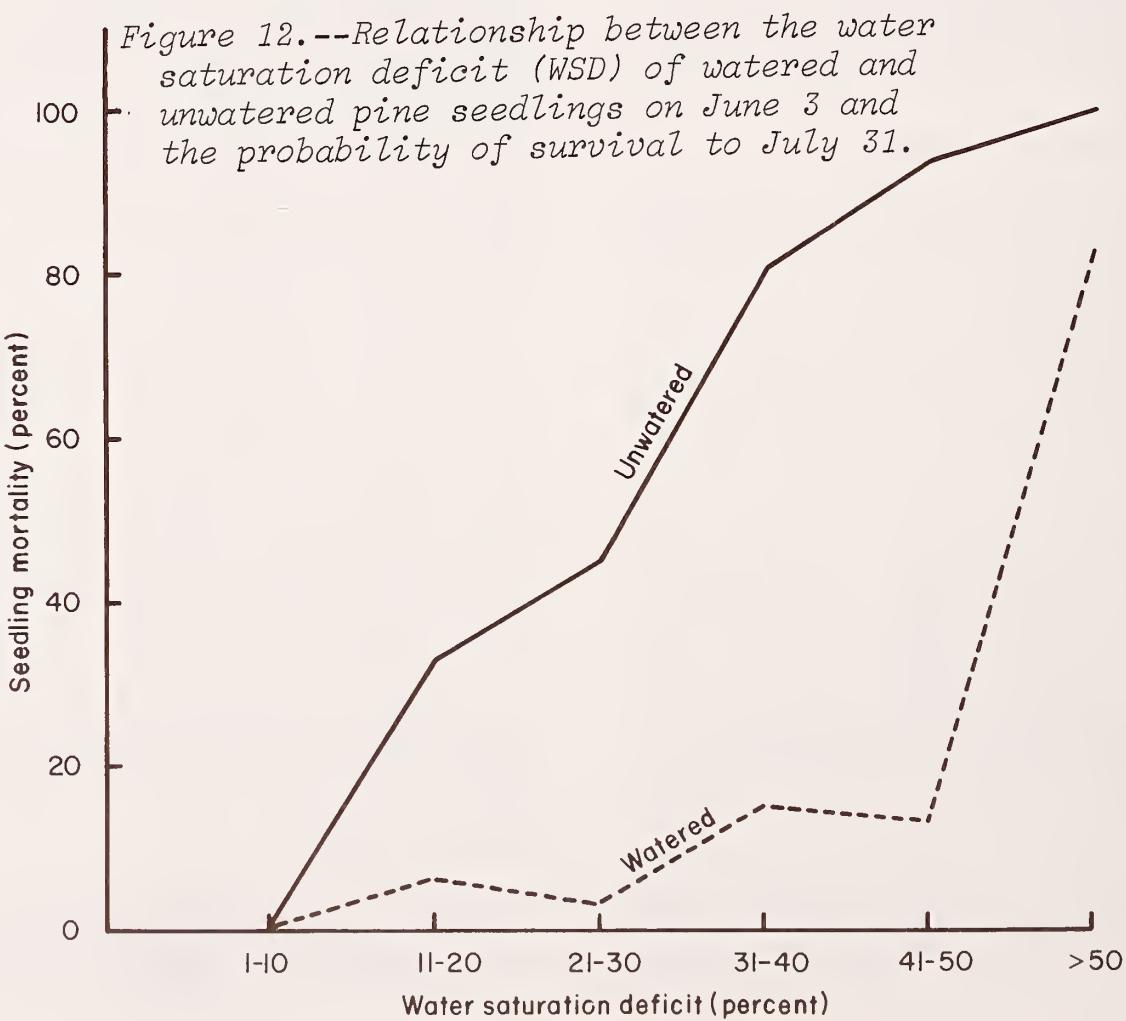
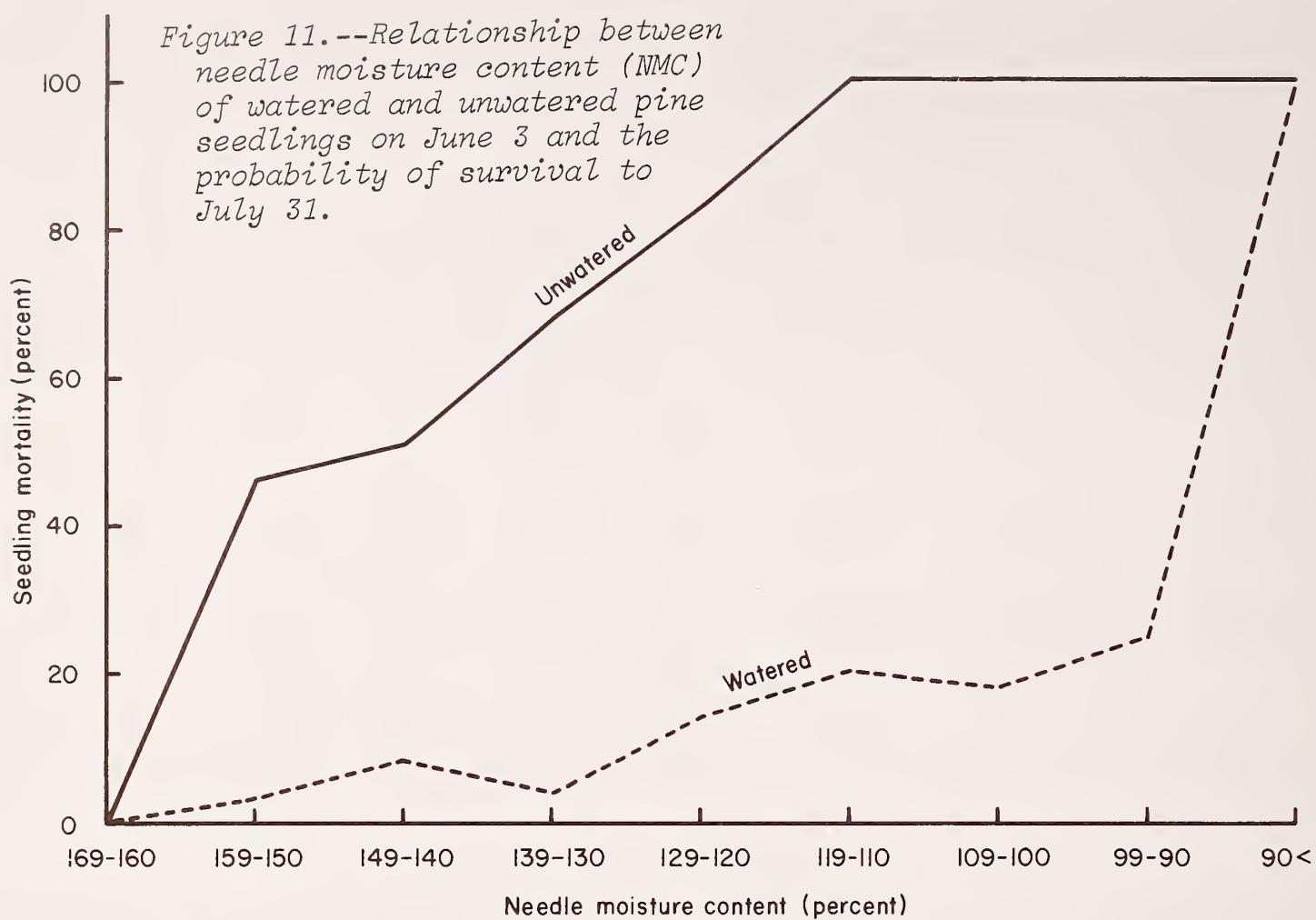
replenished by July and August rains. In contrast, about half of the newly planted pines in the field plots died during the drought period unless watered. Roots of both pine and grasses became dormant as the soil dried out in the planter boxes. When the soil was rewetted and kept moist, the grasses produced many new laterals and a flush of new main roots within 2 to 3 weeks, whereas pines produced only a few new roots after rewetting.

A faster recovery of brome grass over hardwood seedlings during droughts was also reported by Lane and McComb (1948). Richardson (1953) observed that grasses reduced the period of active root growth of Acer seedlings, and noted that grass suppressed laterol root growth more than the main root of tree seedlings. In our study, laterals grew more on pine seedlings grown without grass than in boxes with grass.

Arizona fescue and mountain muhly depleted soil moisture faster and to lower levels than ponderosa pines. Similar results were reported by Pearson (1950) in soil moisture trends in natural grass and denuded areas. Arizona fescue depleted the soil moisture more than mountain muhly, and reduced it to critical levels for plant growth during both the spring and fall droughts. Conrad and Youngmon (1965) found that cold-season pastures suffered more often from midsummer drought than warm-season pastures. Borrett and Youngberg (1965) reported a 45 percent greater use of water in a sapling stand of ponderosa pine with an understory than in one without an understory.

Arizona fescue completed its height growth by about mid-June compared to late summer for mountain muhly. Jameson (1965) found similar times for final height growth of other warm- and cold-season grasses in northern Arizona. In our study both grasses formed new short leaves in the fall that were carried through the winter.

Pine seedlings had a laterol root system advantage over the grasses. Some first-year laterals on the pines exceeded 30 inches in the field experiments. Schuster (1964) reported that the root spread for fescue and muhly averaged only about 1 foot in ungrazed pastures. This widespread root system of pines



is better than the compact root system of grasses because it provides a larger area to tap soil moisture.

Soil moisture remained high below the 16-inch depth for all cover types, with few grass roots below this depth. Similar results were obtained by Schuster (1964) and by Cohen and Strickling (1968). Main roots of all surviving pines extended below the 16-inch depth.

Established pines can tolerate some competition for moisture by grasses. Only 9 percent of the pines that survived the first drought period died during the second growing season. In California, Baron (1962) found that ponderosa pines were able to compete with grasses if the pines were planted before or at the same time the area was seeded with grass. However, pines sustained heavy mortality on areas planted a year or more after the grass seeding. In Arizona, pines from the successful 1919 seedling crop gained dominance over the grasses within 5 years (Arnold 1950). Pearson (1942) reported that pines from the 1919 seedling crop survived in great numbers in competition with muhly but not with fescue.

Pine seedlings grew best in unwatered bare plots. The relatively poor growth of watered seedlings may have been due to excessive water at the lower soil depths. Soil moisture at the 4-inch depth usually remained below field capacity, but moisture at lower depths was not measured in watered plots. Also, the midday soil temperatures of unwatered plots were often considerably higher and more favorable for seedling growth than were the temperatures of watered plots.

There was no evidence that grass roots produced growth inhibitors that suppressed the elongation of pine roots. Pine roots elongated as rapidly in boxes with grass as those without grass as long as soil moisture was adequate (fig. 2). Also, pine seedling survival the first season in the watered field plots was similar for all cover types. The grasses may have produced growth inhibitors when soil moisture stress was high, but the two effects cannot be separated in these data.

Height growth of pine seedlings was a poor indicator of competition. Frequently, ponderosa pines make very little top growth the first year or two after outplanting. Most of the growth during these years is on the root system. Richardson (1953) concluded that height increment was an unsatisfactory basis for comparative growth studies of young trees. Sutton (1967) found that first-year height increment of outplanted spruce seedlings was similar for several levels of root pruning.

Water balance of pine seedlings varied both with season and treatment. The needle moisture content (NMC) and water saturation deficits (WSD) data indicated that the internal moisture stress of needles was low at time of planting and very high during early summer drought. During this drought period, pine seedlings in unwatered plots containing fescue and muhly developed greater internal moisture stresses than pines in denuded or watered plots. After 2 months of summer rains, however, the water balance of unwatered pines was better than that of the watered pines (table 4). This late summer difference in water balance may not be significant, however. The NMC and WSD data recorded on August 31 included statistics for poor-quality watered pines that later died during the fall and winter months (fig. 7). The poor-quality unwatered pines were not included since they had already died during the June drought.

Water saturation deficit (WSD) of pine seedlings on June 3 was a better indicator of survival potential than NMC (figs. 11, 12). Seedlings with WSD values above 25 percent on June 3 had less than a 50-50 chance to survive the June drought. Oppenheimer and Shomer-Ilan (1963) observed internal cellular damage in needles of *Pinus pinea* and *P. halepensis* that reached a WSD of 25 percent.

Pine needles displayed various visual symptoms of drought damage. These symptoms were related to NMC as follows: needles green, 150 percent; needles light green, 111 percent; tips of needles brown, 107 percent; needles with purplish cast,

101 percent; needles with necrotic yellow spots, 84 percent; and needles yellow, 55 percent. The coefficients of variation ranged from 5 percent for seedlings with yellow needles to 17 percent for seedlings with light green needles. A needle moisture content (NMC) (based on ovendry weight) less than 110 percent combined with a WSD greater than 45 percent appears to be the "point of no return" for ponderosa pine seedling survival. Ursic (1961) concluded that an NMC of about 80 percent identified the death point of loblolly pine (*Pinus taeda L.*) seedlings.

Needles subjected to severe drought may not fully recover their former turgidity after the drought is broken. Freshly cut needle fascicles were saturated and subjected to simulated drought conditions by drying until various water saturation deficits (WSD) up to 42.2 percent were reached. The needles were then resaturated and reweighed. Differences in water content between first and second saturations became progressively larger as the WSD increased.

Recommendations

Results of this study show that ponderosa pine should be planted only on grass-free areas. Therefore, if grass is present, it must be killed or removed before trees are planted. Furthermore, since water is in short supply and pine roots reach out several feet, complete site preparation provides the best condition for tree survival and growth. Partial site preparation has been inadequate and is not recommended for the Southwest.

Grass can be effectively killed with dalapon during the summer or removed with a bulldozer in the fall before planting. Current research will determine if grass can be effectively killed with other herbicides at time of planting. Until new research provides other alternatives, dalapon or bulldozer treatment at the recommended times are the best methods to prepare planting areas.

Literature Cited

Arnold, J. F.
1950. Changes in ponderosa pine bunchgrass ranges in northern Arizona resulting from pine regeneration and grazing. *J. Forest.* 48: 118-126.

Baron, F. J.
1962. Effects of different grasses on ponderosa pine seedling establishment.* *USDA Forest Serv., Pacific Southwest Forest and Range Exp. Sta. Res. Note* 199, 8 pp. Berkeley, Calif.

Barrett, J. W., and Youngberg, C. T.
1965. Effect of tree spacing and understory vegetation on water use in a pumice soil. *Soil Sci. Soc. Amer. Proc.* 29: 472-475.

Cohen, O. P., and Strickling, E.
1968. Moisture use by selected forage crops. *Agron. J.* 60: 587-590.

Conard, E. C., and Youngman, V.E.
1965. Soil moisture conditions under pastures of cool-season and warm-season grasses. *J. Range Manage.* 18: 74-78.

Harms, W. R., and McGregor, W. H. D.
1962. A method of measuring the water balance of pine needles. *Ecology* 43: 531-532.

Jameson, D. A.
1965. Phenology of grasses of the northern Arizona pinyon-juniper type.* *U.S. Forest Serv. Res. Note RM-47*, 8 pp. Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colo.

Lane, R. D., and McComb, A. L.
1948. Wilting and soil moisture by tree seedlings and grass.
J. Forest. 46: 344-349.

Larson, M. M.
1962. Construction and use of glass-faced boxes to study root development of tree seedlings.*USDA Forest Serv., Rocky Mountain Forest and Range Exp. Sta. Res. Note 73, 4 pp. Fort Collins, Colo.

Lavin, F.
1961. A glass faced planter box for field observation on roots. *Agron. J.* 53: 265-268.

Oppenheimer, H. R., and Shomer-Ilon, A.
1963. [A contribution to the knowledge of drought resistance of Mediterranean pine trees] *Mitteilungen der Floristisch-soziologischen Arbeitsgemeinschaft N.F.* 10: 42-55.

Pearson, G. A.
1942. Herbaceous vegetation as a factor in the natural regeneration of ponderosa pine in the Southwest. *Ecol. Monogr.* 12: 315-338.

1950. Management of ponderosa pine in the Southwest. U.S. Dep. Agr. Agr. Monogr. 6, 218 pp.

Richardson, S. D.
1953. Root growth of *Acer pseudoplatanus* L. in relation to grass cover and nitrogen deficiency. *Mededelingen van de Landbouwhogeschool te Wageningen/Nederland* 53: 75-97.

Schuster, J. L.
1964. Root development of native plants under three grazing intensities. *Ecology* 45: 63-70.

Sutton, R. F.
1967. Influence of root pruning on height increment and root development of outplanted spruce. *Can. J. Bot.* 45: 1671-1672.

Ursic, S. J.
1961. Tolerance of loblolly pine seedlings to soil moisture stress. *Ecology* 42: 823-825.

*Address requests for copies to the originating office.

USE PESTICIDES CAREFULLY!

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

Pesticides can be injurious to humans, domestic animals, desirable plants, honeybees and other pollinating insects, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and their containers.

Larson, M. M., and Schubert, Gilbert H.
1969. Root competition between ponderosa pine seedlings and grass.
USDA Forest Serv. Res. Pap. RM-54, 12 pp., illus. Rocky
Mountain Forest and Range Experiment Station, Fort Collins,
Colorado 80521.

Soil moisture was the main factor in competition between grass and ponderosa pine seedlings. Pine seedlings survived and grew best on completely cleared plots. New grass roots started growth earlier and grew faster than pine roots. Arizona fescue and mountain muhly depleted soil moisture faster and to lower levels than ponderosa pine. In early June, pine seedlings with a needle moisture content (NMC) under 146 percent and water saturation deficit (WSD) above 25 percent had less than a 50-50 chance of surviving the ensuing drought period.

Key words: *Pinus ponderosa* Laws., *Festuca arizonica* Vasey, *Muhlenbergia montana* (Nutt.) Hitchc., forest management, forest planting.

Larson, M. M., and Schubert, Gilbert H.
1969. Root competition between ponderosa pine seedlings and grass.
USDA Forest Serv. Res. Pap. RM-54, 12 pp., illus. Rocky
Mountain Forest and Range Experiment Station, Fort Collins,
Colorado 80521.

Soil moisture was the main factor in competition between grass and ponderosa pine seedlings. Pine seedlings survived and grew best on completely cleared plots. New grass roots started growth earlier and grew faster than pine roots. Arizona fescue and mountain muhly depleted soil moisture faster and to lower levels than ponderosa pine. In early June, pine seedlings with a needle moisture content (NMC) under 146 percent and water saturation deficit (WSD) above 25 percent had less than a 50-50 chance of surviving the ensuing drought period.

Key words: *Pinus ponderosa* Laws., *Festuca arizonica* Vasey, *Muhlenbergia montana* (Nutt.) Hitchc., forest management, forest planting.

Larson, M. M., and Schubert, Gilbert H.
1969. Root competition between ponderosa pine seedlings and grass.
USDA Forest Serv. Res. Pap. RM-54, 12 pp., illus. Rocky
Mountain Forest and Range Experiment Station, Fort Collins,
Colorado 80521.

Soil moisture was the main factor in competition between grass and ponderosa pine seedlings. Pine seedlings survived and grew best on completely cleared plots. New grass roots started growth earlier and grew faster than pine roots. Arizona fescue and mountain muhly depleted soil moisture faster and to lower levels than ponderosa pine. In early June, pine seedlings with a needle moisture content (NMC) under 146 percent and water saturation deficit (WSD) above 25 percent had less than a 50-50 chance of surviving the ensuing drought period.

Key words: *Pinus ponderosa* Laws., *Festuca arizonica* Vasey, *Muhlenbergia montana* (Nutt.) Hitchc., forest management, forest planting.

Larson, M. M., and Schubert, Gilbert H.
1969. Root competition between ponderosa pine seedlings and grass.
USDA Forest Serv. Res. Pap. RM-54, 12 pp., illus. Rocky
Mountain Forest and Range Experiment Station, Fort Collins,
Colorado 80521.

Soil moisture was the main factor in competition between grass and ponderosa pine seedlings. Pine seedlings survived and grew best on completely cleared plots. New grass roots started growth earlier and grew faster than pine roots. Arizona fescue and mountain muhly depleted soil moisture faster and to lower levels than ponderosa pine. In early June, pine seedlings with a needle moisture content (NMC) under 146 percent and water saturation deficit (WSD) above 25 percent had less than a 50-50 chance of surviving the ensuing drought period.

Key words: *Pinus ponderosa* Laws., *Festuca arizonica* Vasey, *Muhlenbergia montana* (Nutt.) Hitchc., forest management, forest planting.

